

**CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-215**

Little Salmon and related faults, Humboldt County

by
Christopher J. Wills
Associate Geologist
November 16, 1990

INTRODUCTION

The Little Salmon and related faults form a major basin-bounding thrust fault, one of many northwest trending thrusts in Humboldt County north of Cape Mendocino (Figure 1). These faults were mapped by Ogle (1953) as a northwest trending zone over 30 km long. A small stepover near the middle of the fault separates the western strand, the Little Salmon fault, from the eastern strand, the Yager fault. Ogle estimated over 10,000 feet of north-side up movement across the fault. He showed units as young as late Pleistocene to be offset.

The Little Salmon and Yager faults were previously evaluated for zoning under the Alquist-Priolo Special Studies Zones Act by Smith (1982b). He determined that there was not sufficient data at that time to show that the fault was Holocene-active.

Since Smith's Fault Evaluation Report, Gary Carver and co-workers from Humboldt State University have continued studies of the Little Salmon and other faults in the area. These studies (Carver and others, 1986; Carver, 1987; Carver and Burke, 1987; Kelsey and Carver, 1988; Carver and Burke, 1989) have shown that the Little Salmon fault has had multiple displacements and a high slip-rate in late Holocene time. This FER will summarize this recently developed data on Holocene displacement and evidence for fault location from several workers.

SUMMARY OF AVAILABLE DATA

The Little Salmon and Yager faults were mapped by Ogle (1953) as a northwest-trending, northeast-dipping system of thrust faults over 30 km long separating the thick accumulation of Miocene and younger sediments of the Eel River basin from the uplifted Miocene and Franciscan rocks to the north. The total length of the fault zone on land is over 50 km, including traces east of the area mapped by Ogle (Kelsey and Allwardt, 1974; Kelsey and Carver, 1988) other traces may extend up to 40 km offshore, (Figure 1). These faults generally follow the break-in-slope between the hills, to the northeast and alluviated valleys to the southwest (Figure 2a and 2b). Movement on these faults has been related to northward movement of the Mendocino Triple Junction

and subduction of the Gorda Plate (Kelsey and Carver, 1988, McPherson, 1989).

Ogle (1953) estimated that the vertical component of displacement on the Yager fault at Yager Creek (Figure 3) "may be as much as 10,000 feet" (3000 m). His cross section through Tompkins Hill (Figure 2a) shows over 1½ km of dip-slip displacement on the Little Salmon fault. Total displacement in the Humboldt Hill area (Figure 2a) is reported to be "negligible".

Ogle shows Pliocene upper Wildcat Group rocks faulted against upper Pleistocene Hookton Formation along much of the Little Salmon fault. According to Ogle, the fault is concealed beneath upper Pleistocene terrace deposits and Hookton Formation at its northern end. The Yager fault displaces Franciscan and undifferentiated Wildcat Group (which could be Miocene to lower Pleistocene) over Wildcat Group rocks (Miocene to lower Pleistocene).

Pleistocene stratigraphy of the area south and east of Humboldt Bay was defined by Ogle (1953) based on the stratigraphic and geomorphic position of the major units. All of the units in this area are lithologically similar siltstones and sandstones deposited in fluvial to nearshore marine environments. The Carlotta Formation (lower Pleistocene) varies from coarse cobble conglomerate to various forms of floodplain, lake and lagoonal deposits (Ogle, 1953). It is distinguished from the unconformably overlying Hookton Formation by its generally steeper dips and a darker reddish-orange weathering color.

The Hookton Formation ranges from conglomerate to sandstone and siltstone. It has been dated as late Pleistocene because it contains the 600,000 year old Railroad Gulch Ash near its base (WCC, 1980). The Rohnerville Formation and later terrace deposits are also similar to the Hookton and Carlotta Formations. They are distinguished by their position on elevated terraces flanking the Eel River Valley and Humboldt Bay.

The similar appearance of all the late Pleistocene units in this area can make the dating of faults based on a single exposure or trench problematical. The units were originally distinguished partly by their amount of deformation and weathering, both characteristics which can change significantly near faults. The identification of units by the various workers described below are therefore somewhat uncertain. The units named in the text and shown on Figure 2a are the judgement of the different authors.

Studies for the Seismic Safety Evaluation of the Humboldt Bay Power Plant

An in-depth series of studies of the northern end of the Little Salmon fault was conducted for the seismic hazard evaluation of the Humboldt Bay Nuclear Power Plant. Curtis and Hamilton (1972), Earth Science Associates (1975, 1977) and Woodward-Clyde Consultants (1980) performed surface mapping, constructed cross-sections based on drill hole data and logged trenches.

Curtis and Hamilton (1972) show the Little Salmon fault in much the same location as Ogle (1953) but show the trace to be more sinuous, reflecting the expression of a gently dipping fault plane on an irregular surface (Figure 2a). They also projected the fault to the north beneath the north end of Humboldt Hill based on correlations between test borings. Curtis and Hamilton conclude from their subsurface correlations that the Little Salmon fault offsets all units of the Wildcat Group up through the lower Pleistocene Carlotta Formation along its entire length but is overlain by middle to late Pleistocene Hookton Formation and late Pleistocene terrace deposits. Vertical separation across the fault is reported to be about 2500 m in the Tompkins Hill area and about 1200 m in the Humboldt Hill area. Curtis and Hamilton found no evidence for late Quaternary activity on the Little Salmon fault and concluded that it was not active.

Earth Science Associates (1975, 1977) conducted further subsurface and geophysical work. ESA (1975) concluded that the Little Salmon fault in the Humboldt Hill area is overlain by lower Pleistocene Carlotta Formation and that part of the leading edge of the Little Salmon fault is offset by the "Bay Entrance fault" a steeply dipping reverse fault that extends about 10km from north of Fields Landing into the area east of Humboldt Bay (Figure 2a). Further work led ESA to the conclusion that the "Bay Entrance fault" was a younger reverse fault that offsets the Little Salmon fault along much of the east side of Humboldt Bay. The "Bay Entrance fault" offsets late Pleistocene Hookton Formation down to the west between 150 and 250 meters. Earth Science Associates (1977) break the "Bay Entrance fault" into several segments, each of which trends southeasterly parallel to the Little Salmon fault for 2-4 km then bends to a southwest trend and intersects the next segment (Figure 2a). All of these segments were thought to be younger than the Little Salmon fault and steeply dipping, based on correlations between borings, seismic reflection profiles and trench logging. At Holgerson Ranch (locality 1, Figure 2a) a fault between Hookton Formation and Wildcat Group rocks, which dips to the west at about 60°, appears to project into the overlying soil (ESA, 1977, Figure 15). This was called the "Bay Entrance fault" by ESA although it nearly coincides with the Little Salmon fault of Ogle (1953).

More extensive subsurface exploration and mapping by Woodward-Clyde Consultants (1980) shows that the "Bay Entrance fault" mapped by Earth Science Associates (1977) is a set of subsidiary faults in the upper plate of the Little Salmon fault. WCC did not verify the odd 90° curves at the southern end of each segment mapped by ESA (in sections 18 and 33, T4N R1W) but did verify high angle faults in many of the same localities as ESA. WCC concluded that the western strand of the Little Salmon fault, which had not been mapped by ESA, is a major northeast-dipping thrust fault. Several northeast dipping reverse faults in the upper plate of the thrust are related to movement on the major thrust. These faults, the Hookton Channel faults, Bay Entrance faults, Buhne Point fault, and the eastern strand of the Little Salmon fault exposed in trenching at Holgerson Ranch (locality 1, Figure 2a) appear to be subsidiary faults in the upper plate of the main thrust, rather than unrelated faults that truncate the thrust.

Woodward-Clyde Consultants (1980) concluded that the Little Salmon fault and the subsidiary faults in its upper plate all offset the base of the Hookton Formation. They considered movement on these faults in the last 500,000 years likely, making all of these faults "capable" under the criteria of the Nuclear Regulatory Commission. No evidence for Holocene activity of these faults was found by WCC.

Surface Mapping of the Little Salmon Fault

On the south flank of Humboldt Hill, north of College of the Redwoods, Ogle (1953), Curtis and Hamilton, (1972), WCC (1980), Smith (1982b) and Kilbourne and Morrison (1985) have mapped faults or geomorphic features suggestive of faults. All of these features have the same general trend, but few are plotted in the same locations (Figures 2a and 2b). The major geomorphic features, such as the break in slope at the base of Humboldt Hill and scarps along the south side of College of the Redwoods, have been recognized as faults by two or more workers, although they have been plotted slightly differently. More subtle geomorphic features, such as those mapped by WCC (1980) at the Brazil Ranch (locality 3, Figure 2a) and by Smith (1982b) north of College of the Redwoods, were not consistently mapped by different authors.

Landslides on the flanks of Humboldt Hill have been mapped by ESA (1977), Kilbourne and Morrison (1985) and Smith (1982b). Smith described Humboldt Hill as apparently "coming apart (spreading laterally)" along "numerous scarps and troughs". Carver (p.c. 1989) believes that some of these scarps could represent subsidiary faulting in the upper plate of the thrust fault, similar to the eastern trace of the fault to the south. Humboldt Hill has formed as an anticlinal hill because of movement on the underlying Little Salmon fault (Ogle, 1953). Normal faults and graben would be expected to form along the crest of the anticline

due to local extension as the anticline grew. It is not clear how the landsliding, lateral spreading and/or subsidiary faults mapped along the crest of the hill have affected the faults mapped on the lower slopes.

Projection of drill hole data by WCC (1980) shows that the main trace of the Little Salmon fault crosses from Humboldt Bay onto land just northwest of College of the Redwoods. Trenches by WCC (1980) at College of the Redwoods (locality 2, Fig. 2a) exposed a 1 to 2 m wide zone of northeast-dipping thrust faults in middle to late Pleistocene marine deposits (Hookton Formation or younger terrace deposits). Southwest-dipping back thrusts are distributed through most of the exposed part of the hanging wall for 18 meters to the east. Trenches at the Brazil Ranch (locality 3, Figure 2a) show a similar pattern. A northeast-dipping thrust fault at the west end of the trenches displaces Rio Dell Formation, a Pliocene deep-water marine claystone, over either Hookton Formation or more recent marine terrace deposits. Southwest-dipping back thrusts, northeast-dipping thrusts, and normal faults are distributed in the upper plate for about 100 m east of the main thrust.

Trenches by LACO Associates (1989) at College of the Redwoods exposed southwest-dipping thrust faults in late Pleistocene terrace deposits. Presence of these back-thrusts suggest that the master, northeast-dipping thrust fault is nearby and to the southwest. It may be located at the base of the small hill below College of the Redwoods, at the break in slope.

South of College of the Redwoods, the main trace of the Little Salmon fault follows the edge of the Salmon Creek and Little Salmon Creek floodplains. It is expressed geomorphically as a break in slope at the edge of the floodplain and locally as scarps in the floodplains. Mapping by G. Carver (p.c. 1989) and A. Stein (M.S. thesis in progress) of Humboldt State University shows two and locally three traces of the Little Salmon fault in this area (Figure 2b). The western (main) trace mapped by Carver (1989) and Stein (in progress) is at the base of the hills and is defined by scarps and warps in the Holocene flood plain of Little Salmon and Salmon Creeks. The eastern traces originally mapped by Ogle (1953) and mapped in more detail by Stein (in progress) are generally in the hills east of Little Salmon Creek and are mostly obscured by landslides and vegetation. Ogle (1953), Carver (p.c. 1989), and Stein (in progress) generally agree on the location of the eastern trace. Wildcat Group and Hookton Formation are shown to be thrust over Hookton Formation by Ogle and Stein. At Willow Brook (locality 4, Figure 2b) Hookton Formation rocks are shown thrust over alluvium (Stein). Stream profiles by Stein (p.c. 1990) show consistent knickpoints at the traces of the fault, even when rocks on both sides of the fault are equally erodible.

South of Willow Brook, Catfish Lake has formed in a depression adjacent to the headscarp of an active landslide. Jacoby (1989) has dated the formation of the lake by detailed tree-ring analysis of redwoods drowned when the lake formed. If the landslide movement was earthquake triggered, a major earthquake on the Little Salmon fault may have occurred 270 years ago.

Carver and co-workers have trenched both traces of the Little Salmon fault where they cross the floodplains of Salmon Creek and Little Salmon Creek. They have found evidence for Holocene displacement on both traces (localities 5 and 6, Figure 2b) (Carver and Burke, 1989; Carver, p.c. 1989).

Trenches across the western trace of the Little Salmon fault in the Little Salmon Creek valley (locality 5, Figure 2b) show late Pleistocene marine Hookton Formation overlain by late Pleistocene to Holocene colluvium and slopewash which is in turn overlain by Holocene stratified lacustrine and flood plain sediments. These Holocene deposits are cut by a gently dipping fault plane (Figure 4) and warped into an anticline in the hanging wall. Deformation includes sediments younger than 415 years (dated by ^{14}C). Carver and Burke (1989) report 4.5 meters of dip-slip displacement can be associated with the latest earthquake less than 415 years ago. Older Holocene sedimentary units are offset by progressively greater amounts. Correlation and dating of these units shows that the previous two earthquakes occurred less than 870 and 1730 years ago. They were associated with 3.6 and 4.1 meters of dip-slip displacement. Carver and Burke (1989) report that "total dip slip displacement in the last 6200 years is at least 35 m", which yields a late Holocene slip rate of about 5.6 mm/yr.

Trenches across the eastern trace of the Little Salmon fault at Holgerson Ranch (locality 1, Figure 2a) (ESA, 1977) and in the floodplain of Salmon Creek (locality 6, Figure 2b) (Carver p.c. 1989), show similarly deformed very young sediments suggesting that the eastern trace of the Little Salmon fault is also active.

South of Little Salmon Creek the Little Salmon fault crosses Tompkins Hill. Here test borings by WCC (1980) intersected a fault dipping about 20° to the northeast. This fault is shown to trend southeast across the crest of the hill. The four borings by WCC are along one line and do not uniquely define the fault plane. The trace of the fault may have also been based on surface mapping or proprietary oil company subsurface data, but this is not clear from WCC's report.

To the southeast, geomorphic features indicative of recent faulting have been mapped by Smith (1982b) paralleling the trace of the fault mapped by Ogle (1953) and Kilbourne (1985a,b). Linear drainages, breaks in slope and saddles define the fault from Tompkins Hill to Yager Creek (Figures 2a and 2b). North of Hydesville (Figure 3) a break in slope at the base of the hills

defines the main trace of the Little Salmon fault (Smith, 1982b). Other traces of the Little Salmon and Yager faults have been mapped to the north by Ogle (1953) and WCC (1980).

A profile of Yager Creek across the Little Salmon fault measured by Kevin O'Dea (preliminary results of M.S. thesis at Humboldt State University, personal communication, 1990) shows a distinct knickpoint at the projection of the fault. This may suggest that the fault has been active in very recent (late Holocene) time.

East of Yager Creek, Smith (1982b) mapped benches, saddles and linear drainages along the trace of the Little Salmon fault (Figure 3). This geomorphically defined trace generally follows Ogle's (1953) trace, but is more sinuous.

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD CHECKING

Geomorphic evidence for recent faulting was interpreted from aerial photographs and plotted on 7½-minute topographic maps (Figures 2b and 3). Aerial photos of approximately 1:20,000-scale taken by the USDA in 1954 and of 1:31,500 scale taken by the USGS in 1972 were used for this area.

Geomorphic expression of faulting and units offset by faults were field checked on August 31, 1989 and March 19-21, 1990. Geomorphic evidence for recent faulting and the units offset were noted at several localities where evidence for or against Holocene faulting was expected to be particularly clear, based on the aerial photo interpretation.

Small-scale geomorphic indicators of recent movement on the Little Salmon fault are rare. The high rainfall, thick vegetation and abundant landslides tend to obscure or obliterate the neotectonic geomorphology.

The subsidiary reverse faults mapped by Woodward-Clyde Consultants in the Fields Landing area were not confirmed as geomorphic features visible on aerial photos. The Hookton Channel faults, Bay Entrance faults and Buhne Point fault were mapped by WCC based on subsurface data. Parts of all of these faults are under Humboldt Bay. Other parts cross low marine terraces which do not appear to be offset. None of these faults are defined as surface features.

The southwest slope of Humboldt Hill, south of Fields Landing (Figure 2a) follows a smooth curve, suggesting that it could be bounded by a fault. Tonal lineaments and geomorphic features have been mapped along the lower slopes by Smith and WCC, these were generally confirmed on aerial photographs. The linearity of some features and trench exposures by WCC at the Brazil Ranch (locality 3, Figure 2a) suggest that some of the features low on

the southwest flank are faults. Additionally, some features that had not been previously mapped were interpreted from aerial photos. The most prominent of these features trends northwest from College of the Redwoods (Locality 9, Figure 2b). It partly coincides with a fault mapped at the break in slope by Carver (p.c. 1989) but trends more northerly from the terrace at College of the Redwoods into Humboldt Hill.

A tonal lineament along the same trend crosses from the west flank of Humboldt Hill into the Fields Landing area (Locality 10, Figure 2b). This tonal lineament is very linear and resembles a man made feature, such as a buried pipeline, it may not be fault related.

Scarps mapped on the crest of Humboldt Hill by Curtis and Hamilton (1972), Smith (1982b), and Kilbourne and Morrison (1985) were also generally confirmed (Figures 2a and 2b). Those plotted by Smith appear to be more accurately located. These features are low scarps, troughs and tonal lineaments, and are roughly aligned with the north to northwest trend of the Little Salmon fault south of Willow Brook. They could be subsidiary faults similar to the eastern trace but could also be related to landslides or lateral spreading of the ridge. Some of these features, such as the troughs at locality 11 (Figure 2b) are less consistent in orientation and close to the edge of the hill, suggesting that they have formed in the upper part of an active landslide. Nevertheless, even these features have similar orientations and surface forms as scarps to the south and could be related to lateral spreading or secondary faulting.

The main trace of the Little Salmon fault, mapped by Carver (p. c. 1989) was confirmed based on aerial photo interpretation and field checking. It is defined by scarps along the edges of the modern flood plains of Salmon and Little Salmon Creek. Scarps are up to 3 meters high, and as steep as 12°. Trenches by Carver and Burke (1989) at locality 5 (Figure 2a) show that they are fault features and not fluvial.

The eastern trace of the Little Salmon fault is not as well defined. Much of the trace is obscured by vegetation and landslides. At Willow Brook, just south of College of the Redwoods (locality 4, Figure 2b), the Pleistocene Hookton Formation mapped by Stein (in progress) has been faulted over dark gray, plastic, clay alluvium of presumed Holocene age. The clay has not been dated but contains abundant fresh-appearing wood fragments, some of which are altering to vivianite. The contact between the Holocene clay and the overlying rock was not exposed in the active clay mine when it was visited by C. Wills and G. Carver on 8/31/89, but Carver reports that it is probably a fault contact. The contact dips less than 10° to the east. Total displacement since the clay was deposited is apparently over 30 m.

To the south, the east trace of the Little Salmon fault is obscured by dense forest and the Catfish Lake landslide. The fault was found in a trench across this trace by ESA (1977) at Holgerson Ranch (locality 1, Figure 2a). A portion of this fault north of Salmon Creek and across the Salmon Creek floodplain could be confirmed by geomorphic features. The scarp in the Salmon Creek floodplain is over 3 meters high and slopes at up to 10° to the west (Locality 6, Figure 2b). This well-defined scarp in young deposits confirms that this trace of the fault is sufficiently active (Hart, 1988).

South and east of the Little Salmon Creek valley, geomorphic evidence for recent movement on the Little Salmon Fault was largely obscured by dense forest. However, the trace of the fault is generally defined by a broad break-in-slope that can be traced across Tomkins Hill, near the location of the fault mapped by previous workers. The contact between a dark grey siltstone above the contact and sandstone below is probably the fault, although no exposure of the fault itself was found in the field.

The fault again follows the base of the hills southeast of Newburg and geomorphic evidence for recency becomes more common. Geomorphic features mapped by Smith (1982b) were generally confirmed and some additional features were mapped (figure 3). Sharp scarps (with slope angles up to 70° at locality 7 (Figure 3)) and breaks in slope suggest that this portion of the fault has also been active in late Holocene time. A back-facing scarp at locality 8 (Figure 3) is the least eroded scarp observed in the area. At its western end it is less than 1 meter high and has a maximum slope angle of 26°. About 50 meters to the east, the back-facing scarp reaches a height of over 5 meters and a slope of 30°, probably enhanced by spring sapping. Within another 100 m, the scarp diminishes in height, bounds a closed depression and dies out. A southwest-facing scarp begins on the other side of the closed depression and continues to the east.

A subsidiary fault south of the Little Salmon fault has formed a sharp scarp in late Pleistocene terrace deposits just west of Yager Creek. This fault was originally mapped by WCC (1980), modified based on aerial photo interpretation by Smith (1982a) and confirmed for this study (using the same aerial photos as used by Smith (1982a)). This short fault is parallel to and less than 1 km north of the Goose Lake fault, which was zoned in 1983 based on the work of Smith.

Other linear drainages and saddles north of this trace probably follow other traces of the Little Salmon and Yager faults. Yager Creek is notably more incised upstream of the Yager fault, as mapped by Ogle (1953) (Figure 3), than it is downstream, suggesting recent, north-side-up offset, although this could also be due to more resistant bedrock upstream from the fault. The trace of the Yager Fault mapped by Ogle could not be confirmed as a geomorphic feature east of Yager Creek.

East of Yager Creek the Little Salmon fault is probably marked by broad breaks-in-slope, saddles and linear drainages similar to those on Tompkins Hill. The area is heavily forested and no small-scale features indicating recent displacement on the fault could be observed on the available aerial photos. The broad geomorphic features shown on the topographic map suggest Holocene displacement but do not constitute a "well defined" trace (Hart, 1988). Access to the Yager Creek area was not permitted by Pacific Lumber Company, the land owner.

SEISMICITY

The Little Salmon fault lies in a seismically active area north of the Mendocino triple junction. Earthquakes of magnitude 6.0 or greater have struck the Eureka area in 1909, 1915, 1918, 1922, 1923, 1925, 1932, 1941, 1945, 1954, 1956, 1960, and 1980 (Toppozada and Parke, 1979; Kilbourne and Saucedo, 1981). Over 80% of the earthquakes, however, are related to the deformation of the Gorda Plate beneath the North American Plate (Smith and Knapp, 1980; McPherson, 1989). Of the earthquakes that are occurring within the North American Plate, none can definitely be related to the Little Salmon-Yager fault system.

CONCLUSIONS

The Little Salmon fault is an active thrust fault about 50 km long, which may extend offshore up to 40 km (Fig. 1). It offsets a thick section of Neogene sedimentary rocks along the north side of a sedimentary basin undergoing compression due to plate interaction north of the Mendocino triple junction and possible subduction of the Gorda Plate.

The main strand of the Little Salmon fault has been mapped by Carver (p.c. 1989) along the east side of the Salmon Creek and Little Salmon Creek floodplains. It is well defined by scarps, breaks-in-slope and tonal lineaments and has been confirmed by trenching at localities 2, 3 and 5. Trenches by Carver and Burke (1989) have shown that the Little Salmon fault offsets Holocene sediments. Dating of these sediments and measurements of offsets resulted in a calculated slip rate on the main strand of the fault of approximately 5.6 mm/yr.

To the east of Tompkins Hill the main trace has been mapped by Smith (1982b) and Wills (this study). It is similarly well defined by scarps and breaks in slope. Across Tompkins Hill the fault has been mapped by Ogle (1953) and confirmed by borings (WCC, 1980). It is not as well defined across this rugged topography but could be shown as an "inferred fault" on the Special Studies Zone Map.

An eastern strand of the Little Salmon fault has been mapped by Carver (p.c. 1989) and Stein (M.S. thesis in progress) through the hills east of Salmon Creek. This trace generally follows the trace

mapped by Ogle (1953) but is now thought to be a subsidiary fault in the upper plate of the Little Salmon fault. This trace is extensively covered by landslides and vegetation and most of it cannot be mapped based on geomorphology from aerial photographs. Detailed mapping and measurement of stream profiles by Stein (in progress), an exposure at locality 4, and trenching at localities 1 and 6 (Figure 2b) has resulted in this trace being "sufficiently active and well defined".

The trace of the Little Salmon fault mapped by Ogle (1953) north of Hydesville may be a similar subsidiary trace in the upper plate of the Little Salmon fault and can be verified locally as breaks in slope, saddles and linear drainages. It could be considered "sufficiently active" based on its similar structural relationship to the main strand as the "eastern trace" mapped by Stein (in progress). The geologic mapping by Ogle (1953) is detailed enough for this trace to be shown as an "inferred fault" on the Special Studies Zones map.

East of Yager Creek the general correspondence between the Little Salmon fault mapped by Ogle (1953) and the broad breaks-in-slope suggests that this part of the fault is also active. The mapping by Ogle and some traces from the interpretation of aerial photographs are sufficiently "well defined" for zoning as inferred faults. The fault may continue to the east of the Hydesville quadrangle (Kelsey and Allwardt, 1974; Jennings, 1975) but was not evaluated.

The Yager fault is not associated with any similar large scale geomorphic features and small scale features cannot be observed through the dense forest cover in the area. Because access to the Yager Creek area was denied by the landowner, no field checking of the Yager fault was done. Based on the available information the Yager fault is not "sufficiently active and well defined" for zoning purposes.

The minor faults mapped by WCC (1980) in the upper plate of the Little Salmon fault near Fields Landing (The Hookton Channel, Bay Entrance and Buhne Point faults) were not mapped as surface features and have no geomorphic expression. They therefore do not meet the criteria of "well defined" for zoning purposes.

Many short scarps, side-hill benches and troughs were mapped on Humboldt Hill by Smith (1982b) and Wills (this study). Some of these features resemble extensional features that form near the headscarps of landslides. Others are relatively straight and could be due to normal faulting in the upper plate of the thrust fault or lateral spreading of the ridge during earthquakes. All of these features are potential seismic hazards and cannot be distinguished from secondary faults based on the landforms.

RECOMMENDATIONS

The traces of the Little Salmon fault, highlighted in yellow on Figures 2b and 3 are sufficiently active and well defined for zoning under the Alquist-Priolo Special Studies Zones Act. References on the Fields Landing and Fortuna quadrangle should be Carver and Burke (1989), Ogle (1953), Smith (1982b), and Wills (this study). References on the Hydesville quadrangle should be Ogle (1953), Coppersmith (1980), Smith (1982a,1982b), and Wills (this study).

A note on the Fields Landing quadrangle Special Studies Zones Map should state "Faults obscured by massive landsliding" and indicate the northwestern end of Humboldt Hill.

*Report reviewed;
recommendations approved.
Earl W. Hart
CEG 935
12/27/90*

C.J. Wills

C.J. Wills
C.E.G. 1423

REFERENCES

- Carver, G.A., 1987, Late Cenozoic tectonics of the Eel River basin region, coastal northern California, in Schymiczek, H., and Suchsland, R., editors, Tectonics, sedimentation and evolution of the Eel River and associated coastal basins of northern California: San Joaquin Geological Society, Miscellaneous Paper 37, p. 61-72.
- Carver, G.A., and Burke, R.M., 1989, Final Report, trenching investigation of northwestern California faults, Humboldt Bay Region, Unpublished report submitted to USGS, Grant # 14-08-0001-G1082, 20 p.
- Carver, G.A., and Burke, R.M., 1987, Investigations of late Pleistocene and Holocene thrust faulting in coastal California north of Cape Mendocino, in Jacobson, M.L., and T.R. Rodriguez, compilers, National earthquake hazards reduction program, summaries of technical reports volume XXIII: U.S. Geological Survey Open File Report 87-63, p. 165-168.
- Carver, G.A., Burke, R.M., and Kelsey, H.M., 1986, Quaternary deformation studies in the region of the Mendocino triple junction, in Jacobson, M.L., and R.R. Rodriguez, compilers, National earthquake hazards reduction program, summaries of technical reports volume XXI: U.S. Geological Survey Open File Report 86-31, p. 58-62.
- Coppersmith, K.J., 1980, Summary of exploration locality investigation, in Woodward-Clyde Consultants, Evaluation of the potential for resolving the geologic and seismic issues at Humboldt Bay Power Plant Unit Number 3: unpublished consulting report prepared for Pacific Gas and Electric Company, Appendix B, 107 p.
- Curtis, G.H., and Hamilton, D.H., 1972, Geology of the southern Humboldt Bay area and the Humboldt Bay power plant site: Earth Science Associates, unpublished consultants report, 47 p. and appendices.
- Earth Science Associates, 1975, Geology of the Humboldt Bay region, with special reference to the geology of the Humboldt Bay Power Plate Site and vicinity: copy this unpublished consulting report prepared for Pacific Gas and Electric Co., 50 p.
- Earth Science Associates, 1977, Humboldt Bay power plant site geology investigation: unpublished consulting report prepared for Pacific Gas and Electric Co., 101 p.

- Hart, E.W., 1988, Fault rupture hazard zones in California: Division of Mines and Geology Special Publication 42, 24 p.
- Jacoby, G.C., 1989, Very precise dating of prehistoric earthquakes in California using tree-ring analysis in M.L. Jacobson, compiler, National earthquake hazards reduction program, summaries of technical reports volume XXVIII: U.S. Geological Survey Open File Report 89-453, p. 129-133.
- Jennings, C.W., 1975, Fault map of California with locations of volcanoes, thermal springs, and thermal wells: California Division of Mines and Geology, Geologic Data Map No. 1, scale 1:750,000.
- Kelsey, H.M., and Allwardt, A.O., 1974, Geologic Map of the Van Duzen River Basin, Humboldt and Trinity Counties, California in California Department of Water Resources, 1975, Van Duzen River Basin Environmental Atlas, Plate 8, scale 1:36,200.
- Kelsey, H.M., and Carver, G.A., 1988, Late Neogene and Quaternary tectonics associated with the northward growth of the San Andreas transform fault, northern California: Journal of Geophysical Research, v. 93, no. B.5, p. 4797-4819.
- Kilbourne, R.T., 1985, Geology and geomorphic features related to landsliding, Fortuna 7.5' quadrangle, Humboldt County, California: California Division of Mines and Geology Open-File Report 85-1, scale 1:24,000
- Kilbourne, R.T., 1985, Geology and geomorphic features related to landsliding, Hydesville 7.5' quadrangle, Humboldt County, California: California Division of Mines and Geology Open-File Report 85-2, scale 1:24,000
- Kilbourne, R.T. and Morrison, S.D., 1985, Geology and geomorphic features related to landsliding, Fields Landing 7.5' quadrangle, Humboldt County, California: California Division of Mines and Geology Open-File Report 85-4, scale 1:24,000
- Kilbourne, R.T. and Saucedo, G.J., 1981, Gorda Basin earthquake, northeastern California: California Geology, v. 34, no. 3, p. 53-57.
- LACO Associates, 1989, College of the Redwoods Library Addition: Geotechnical Investigation: unpublished consulting report, 26 p. and appendices (C-718).
- McPherson, R.C., 1989, Seismicity and focal mechanisms near the Mendocino triple junction, northern California: Humboldt State University, unpublished M.S. thesis, 81 p.

- Ogle, B.A., 1953, Geology of the Eel River Valley area, Humboldt County, California: California Division of Mines Bulletin 164, 128 p., 6 plates, scale 1:62,500.
- Smith, S.W. and Knapp, J.S., 1980, The northern termination of the San Andreas fault, in Streitz, R and R. Sherburne, editors, Studies of the San Andreas fault in northern California: California Division of Mines and Geology Special Report 140, p. 153-164.
- Smith, T.C., 1982a, Goose Lake and related faults, Humboldt County: California Division of Mines and Geology Fault Evaluation Report FER-130 (unpublished)
- Smith, T.C., 1982b, Little Salmon and Yager faults, Humboldt County: California Division of Mines and Geology Fault Evaluation Report FER-142 (unpublished)
- Stein, A., (in progress): M.S. thesis project Humboldt State University, tectonic geomorphology along a portion of the Little Salmon fault.
- U.S. Department of Agriculture, 1954, Aerial photographs, flight CVL, numbers 7N, 81-82, 93-94, 168-169, and 9N, 127-130, black and white, vertical, scale 1:20,000.
- U.S. Geological Survey, 1972, Aerial photographs, flight GS-VCZP, roll 3, numbers 97-102, 116-120, 147-151, and 160-163, black and white, vertical, scale 1:31,500.
- Woodward-Clyde Consultants, 1980, Evaluation of the potential for resolving the geologic and seismic issues at the Humboldt Bay Power Plant Unit Number 3: Unpublished consulting report prepared for Pacific Gas and Electric Company, 145 p.



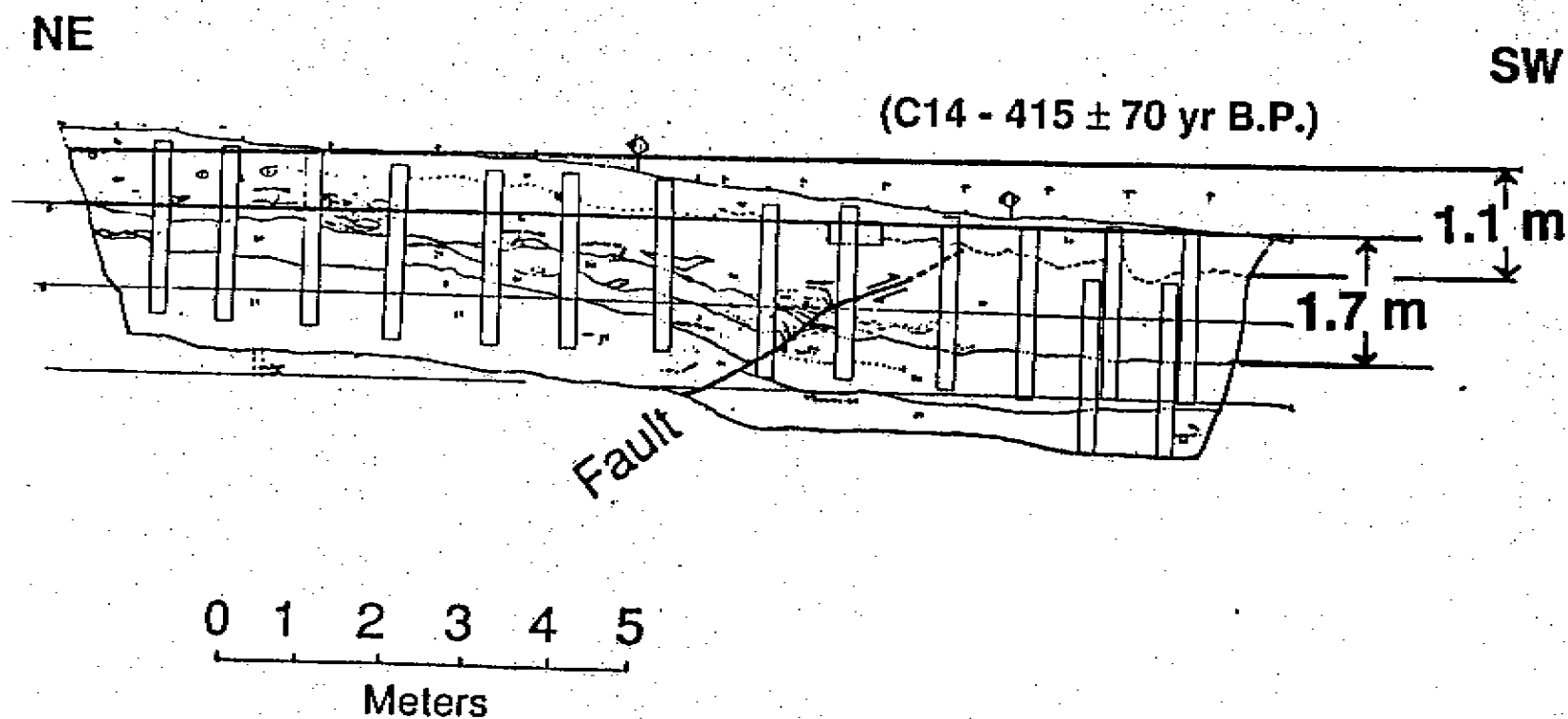
FER-215, Photo 1

Fault scarp at locality 8, (Figure 3). Scarp is about 30 cm high at right (near driveway) and more than 5 m high at left (near well). View to southwest toward Hydesville. This scarp is the result of movement on a minor backthrust. The major strand of the fault is out of view at the base of the hill behind the house in the center of this photo.

Little Salmon Fault

West Trace

Little Salmon Creek Site



FER-215, Figure 4

Trench log across the Little Salmon fault at locality 6 (Figure 2a) by Carver and Burke (1989) showing offset of Holocene floodplain sediments